SuperTruck – Development and Demonstration of a Fuel-Efficient Class 8 Tractor & Trailer
Vehicle

DOE Contract: DE-EE0003303
Project Officer: Ralph Nine

Navistar Principal Investigator: Russ Zukouski

DOE MERIT REVIEW

12 June, 2015

Project ID: ACE059

Program Overview

Timeline

Project Start:	October 2010
Project End:	Sept 2016
% Complete:	62%

Partners

Navistar	Principal Investigator, Vehicle Systems Integrator Controls Systems, Engine & Vehicle Testing
Bosch	Fuel Systems
Wabash	Trailer Technologies
Argonne ANL	Dual Fuel Engine testing, simulation & evaluation
Lawrence LLNL	Aerodynamic CFD

Barriers

Achieving 50% freight efficiency while balancing Voice of Customer Needs

Alignment with business needs

Reducing tractor weight while adding new systems

Budget

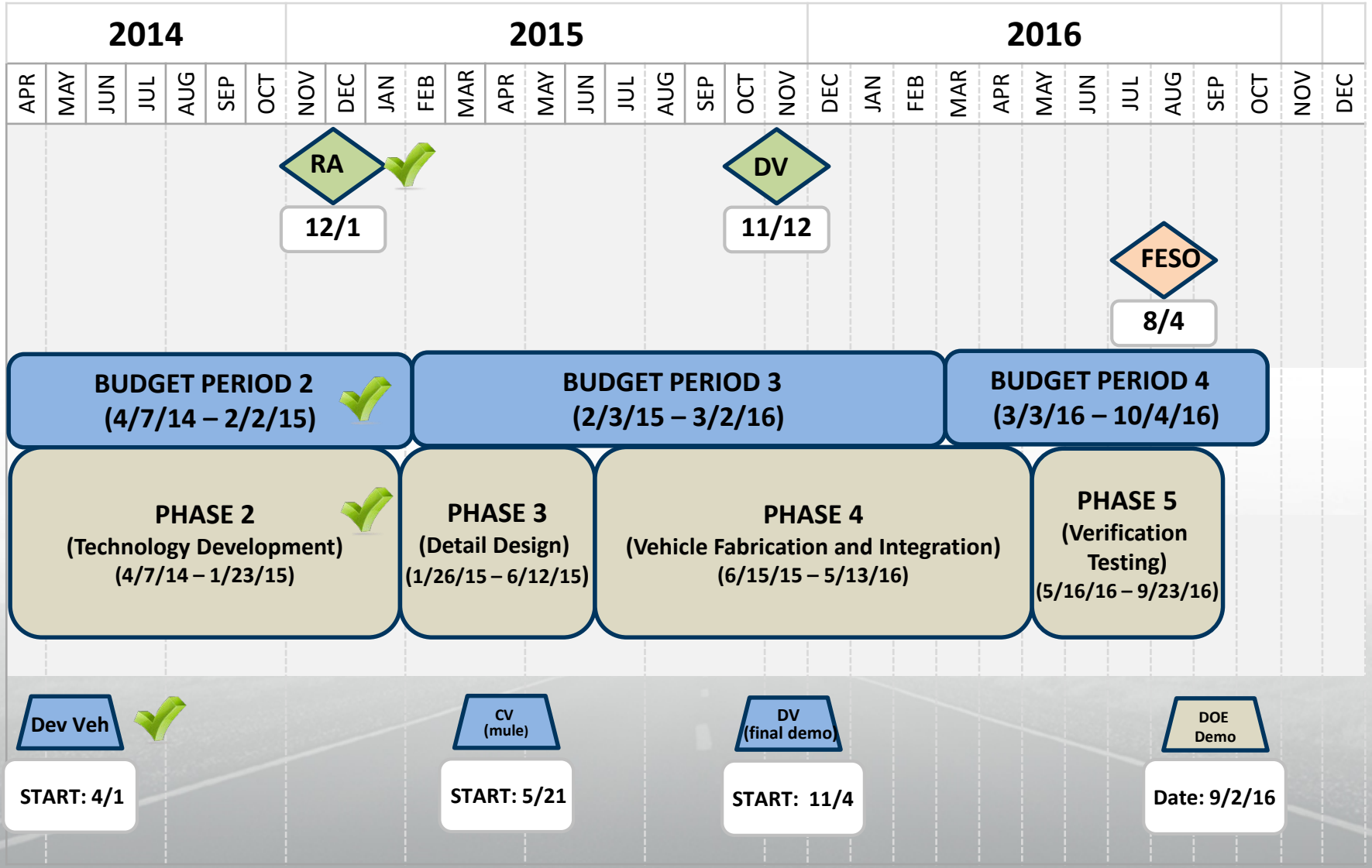
Total Funding:	$76,178,386
DOE:	$35,754,460
Prime:	$40,423,926
Funding FY2014	$6,025,644
Funding for FY2015	$8,965,646

Goals & Objectives - Relevance

- Project Goal
  - Demonstrate 50% improvement in freight efficiency of a combination Tractor-Trailer
  - Attain 50% BTE Engine
  - Demonstrate path towards 55% BTE Engine

- March 2014 to March 2015 Goals
  - ✓ – Restart / ramp up program after “Pause” period
  - ✓ – Re-evaluate technology concepts in lieu of original dual mode hybridization concept for vehicle
  - ✓ – Build & evaluate mule truck
  - ✓ – Complete Phase 2 (*concept phase/ technology roadmap*)

Program Timing



Vehicle Partnerships and Completed tasks

Apr-**12** | Oct-12 | Apr-**14** | Apr-**15** | Apr-**16**

PAUSE

Navistar

- ✓ *Vehicle systems integrator*
- ✓ *Control Systems*
- ✓ *Base Engine*

Phase II

- ✓ *Concept technologies chosen*
- ✓ *48.3% BTE achieved*
- ✓ *Load biasing dev truck built & evaluated*
- ✓ *Material procured for Mule build*
- ✓ *Engine Design*
- ✓ *Controls deployment*

Phase III-V

50% + FE

Wabash National

- ✓ *Trailer Technologies*

50% FE

BOSCH

- ✓ *Fuel Systems*

- ✓ *Adv comb with FIS strategies*

50+ BTE Path 55% BTE

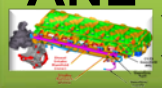
LLNL

- ✓ *Computational Fluid Dynamics*

- ✓ *Computational Fluid Dynamics*

50% FE

ANL



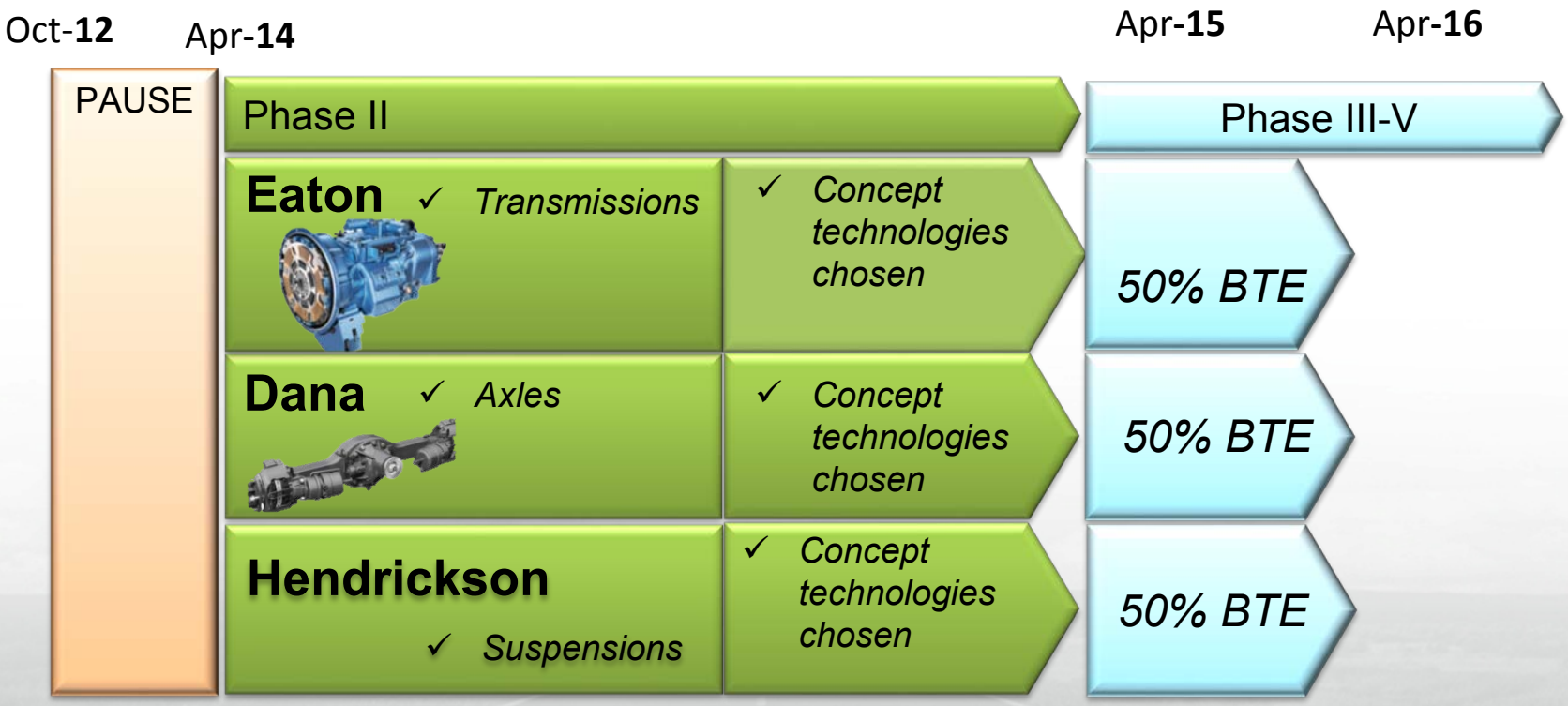
- ✓ *Engine Design*
- ✓ *Controls deployment*
- ✓ *Fuel Reactivity testing*

- ✓ *VVA* ✓ *1D/3D simulations*
- ✓ *Reduction of Parasitic*
- ✓ *Fuel Reactivity testing*

50+ BTE Path 55% BTE

FE = Freight Efficiency (ton-miles/gal)

Vehicle Collaborators & Completed tasks



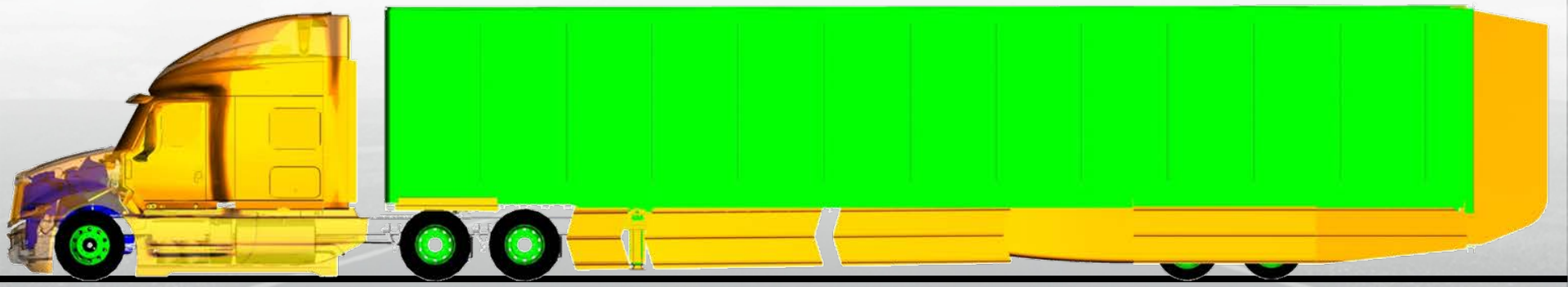
Technical Approach

Four Distinct Areas of Development

NAVISTAR®

Lightweighting	Rolling Resistance	Aerodynamic Improvement	Powertrain Technologies
• Lightweight Frame • Composite Materials • Lightweight Trailer	• Energy Recovery • Reduced Parasitic	• Tractor • Trailer	• High Efficiency Drivetrain • Stop/Start Idle Reduction • Waste Heat Recovery • eTurbo • Adv. After treatment • Friction Reduction

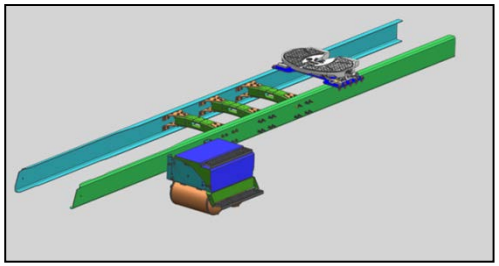
Total Est. FE Improvement 50% +



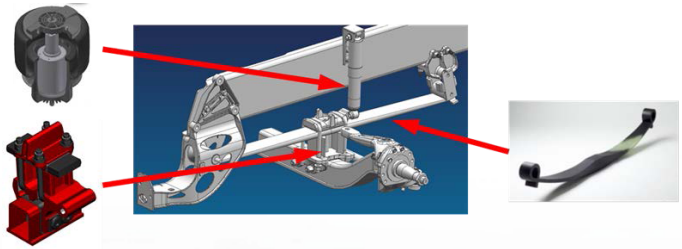
FE = Freight Efficiency (ton-miles/gal)

Approach - Lightweighting

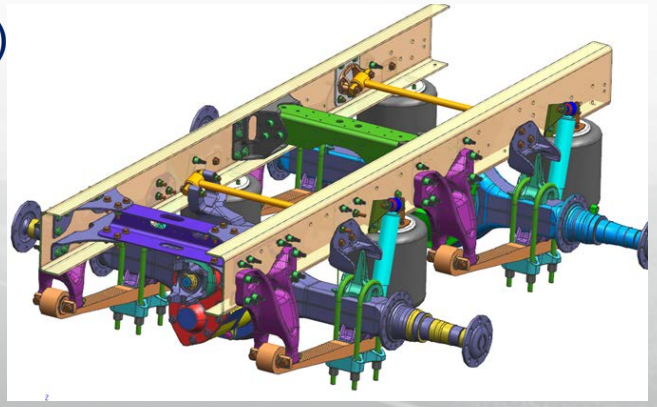
- Frame System (~.5-1% FE[1])
  - Frame w/ Lightening Holes
  - Aluminum Cross Members



- Wabash National Trailer (~4-5% FE[1])



- Hybrid Front Suspension (~.5-1% FE[1])
  - Aluminum Components
  - Composite Leaf Springs
- Lightweight IROS Rear Suspension (~.5-1% FE[1])
  - Redesign
  - Aluminum Cross members
  - Composite Springs

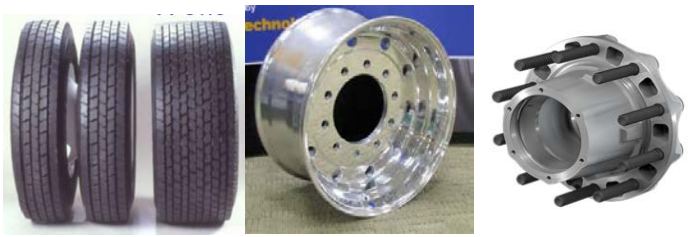


1. Calculated, simulation or test data
2. Improvements shown relative to SuperTruck mule vehicle

FE = Freight Efficiency (ton-miles/gal)

Approach - Lightweighting

- Tire & Wheel Equipment (~1-2% FE[1])
  - Wide Base Single Rear Tires
  - Aluminum Rims/Hubs
  - Steel Shell Brake Drums



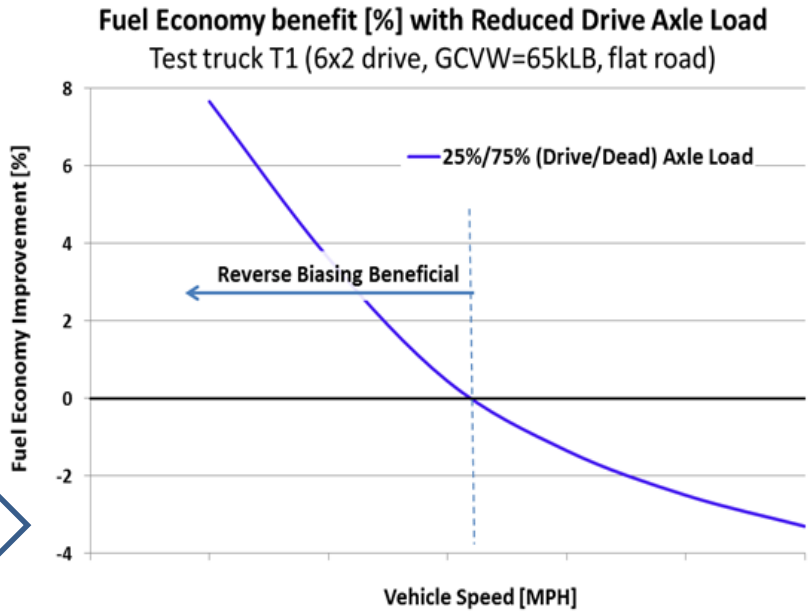
- Lightweight Driveshafts and Axles (~1-2% FE[1])
  - 6x2 Configuration
  - "Diamond Series" Aluminum Driveshaft

1. Calculated, simulation, or test data
2. Improvements shown relative to SuperTruck mule vehicle

FE = Freight Efficiency (ton-miles/gal)

Approach - Rolling Resistance Reduction

- Development truck was configured to evaluate new suspension technologies:
  - 6x2 configuration with axle load control
  - Liftable dead axle
- Tests were performed on a closed loop track
- Fuel economy was demonstrated due to reduced rolling resistance using load biasing

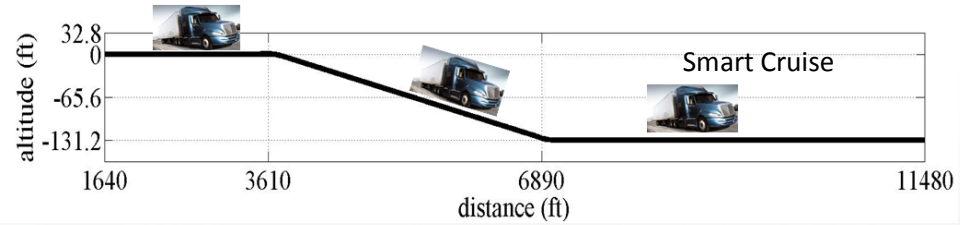


Approach - Rolling Resistance

- Rolling Resistance (~7-8% FE[1])
  - Wide-Base Single Tires
  - Timken PDFE high efficiency bearings

- "Smart" Subsystems (~6-7% FE[1])
  - Cruise Control
  - High Temperature engine cooling
  - Air Compressor
  - Alternator /Generator
  - A/C compressor

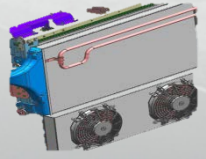
Single 4% downhill: 6.86% fuel saving, and 0.1% travel time increasing.

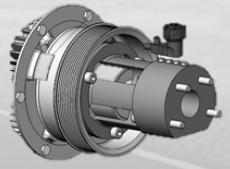


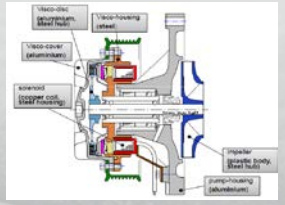
48 V A/C Compressor

Variable water pump

Integrated air compressor







3-Speed Fan Clutch

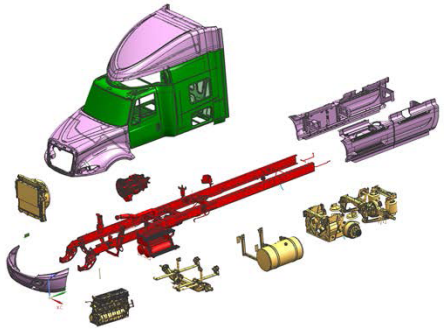
1. Calculated, simulation, or test data
2. Improvements shown relative to SuperTruck mule vehicle

FE = Freight Efficiency (ton-miles/gal)

Approach - Aerodynamic Improvements

- Wind tunnel results
- Re-designed Cab and Aerodynamics
  - (10-12% FE[1])
  - Aerodynamic Improvements
  - Weight Reduction

All New Exterior Scope
All New Cab in White
Modified
Carryover



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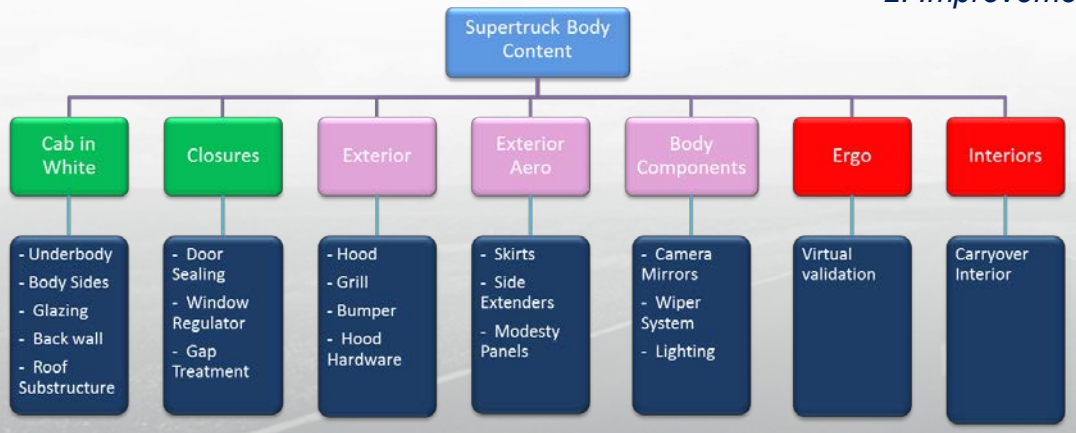
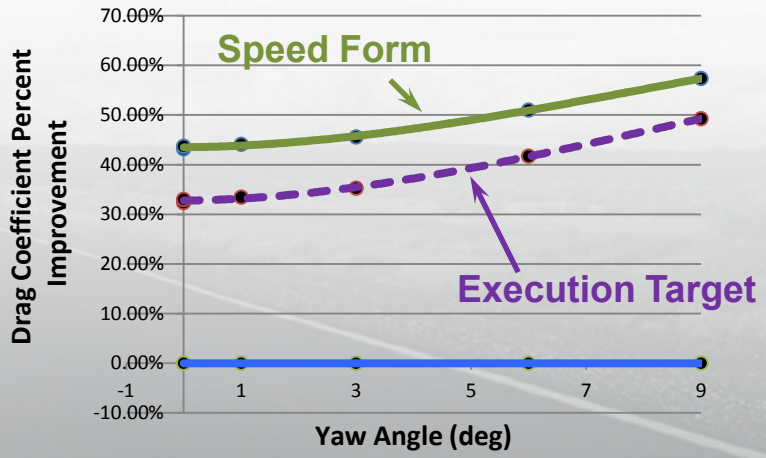


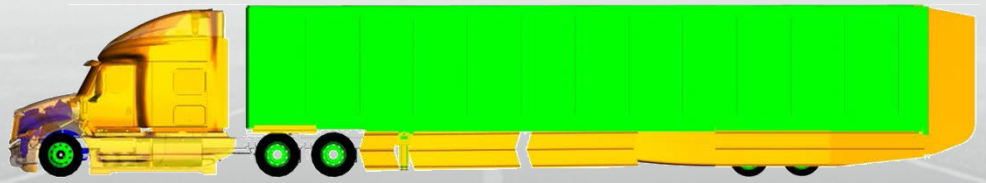


FE = Freight Efficiency (ton-miles/gal)

Approach - Aerodynamics Improvements

- Wind tunnel results
- Trailer Systems(~17-19% FE[1])
  - Trailer Boat Tail
  - Trailer Skirts
  - Trailer Bogie Treatment
  - Trailer Wheel Covers
  - Drive Wheel Covers
- Dynamic Pitch Control (~2-3% FE[1])
  - Trailer Bogie Height Reduction
  - Front Axle Height Reduction

Pitch Control



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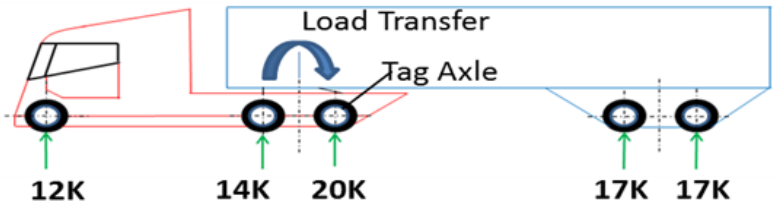
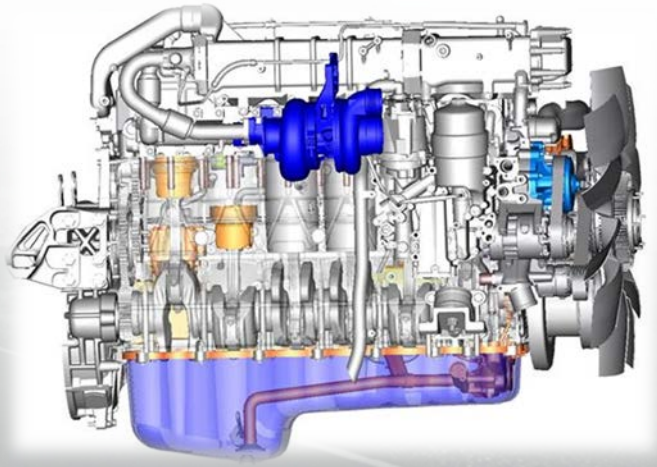
FE = Freight Efficiency (ton-miles/gal)

Approach - Powertrain Technologies

- Development truck results
  - 6x2 Drivetrain (~2-3.0% FE[1])
    - 6x2 Configuration
    - Direct-Drive Eaton UltraShift
    - Load Biasing Suspension



- 50% BTE engine development work
  - Currently at 48.3% in dyno cell
  - See engine presentation *(ace059_zukouski_2015_o)* for in-depth work on:
    - Combustion
    - Air System
    - Friction Accessories
    - Aftertreatment
    - WHR



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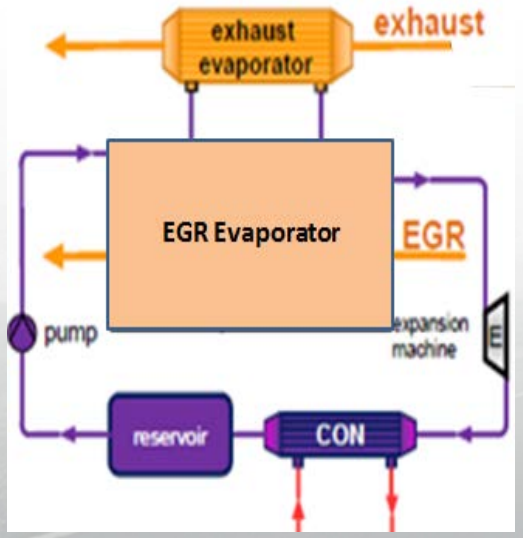
FE = Freight Efficiency (ton-miles/gal)

Approach - Powertrain Technologies

- Stop / Start technology includes
  - Long life starter
  - Software strategy
  - NiZn Batteries
  - Simulation shows

Route \ Metric	Weighted Impact
Kentucky	0.20%
Illinois	0.65%
Illinois City cycle	0.71%
Total	1.56%

- WHR
  - Estimated ~3-4% FE[1]



ORC System

FE = Freight Efficiency (ton-miles/gal)

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2014-15 Accomplishments

Four Distinct Areas of Progress

NAVISTAR®

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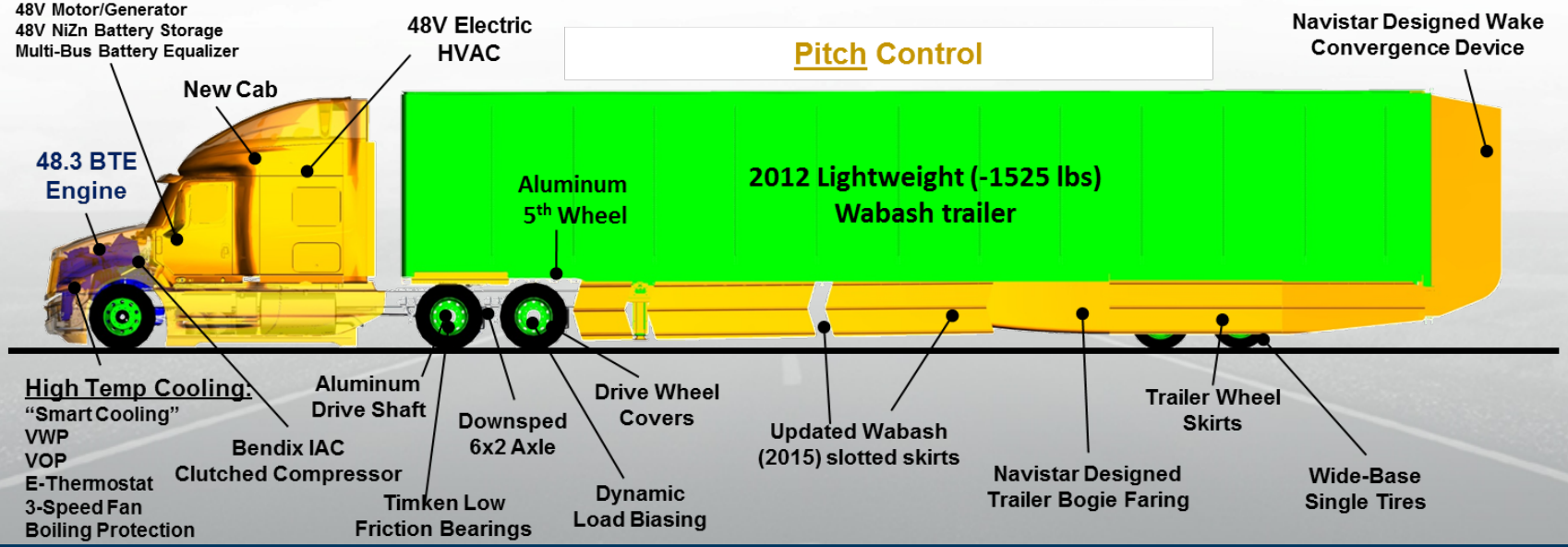
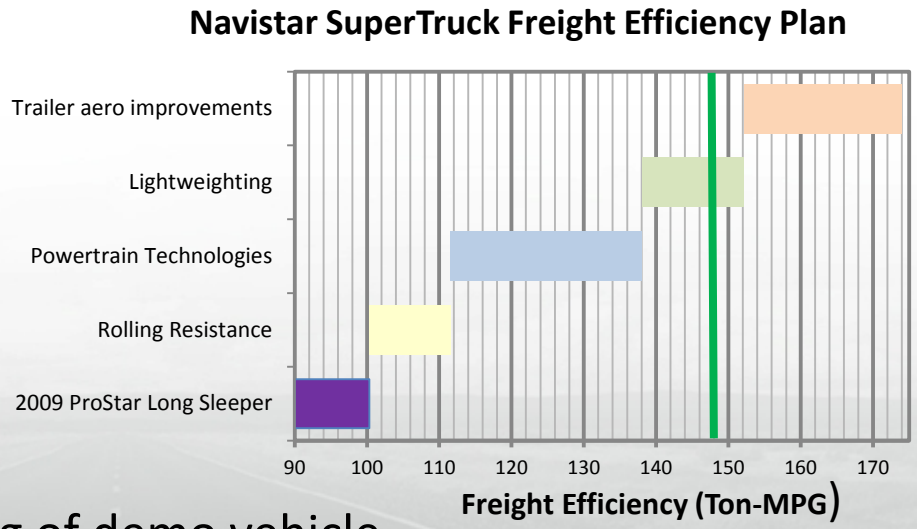
Technology road map developed



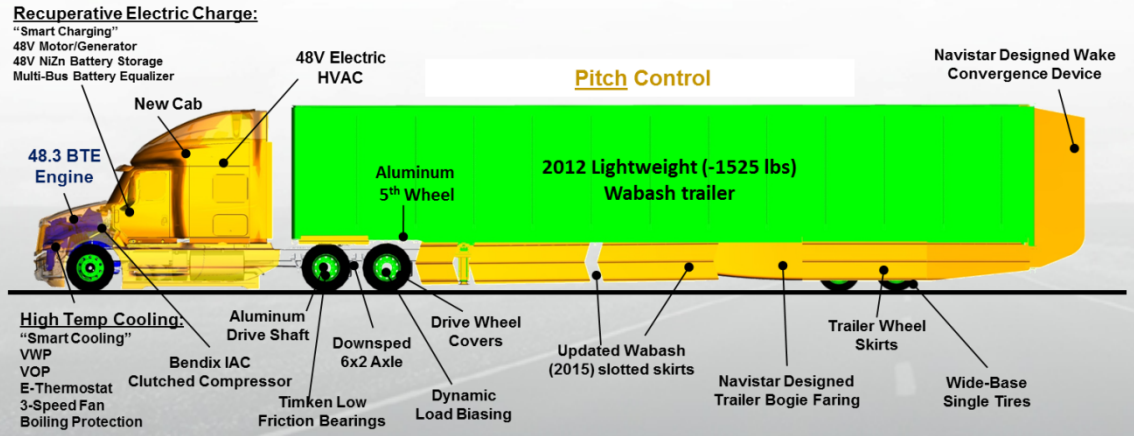
Future Work

- 2015
  - Target completion of development truck – April / 2015
    - Validation plan: 2 months control development for axle Load Biasing and dynamic ride Height Control
  - Target completion of development truck – June / 2015
    - Enhanced Charging
    - Smart Cooling
    - Smart Cruise
    - 50% +BTE engine
    - Electric HVAC
  - Increasing collaborations
- 2016
  - Build, final testing, & optimizing of demo vehicle
  - Presentation to DOE



Project Summary

1. Several aerodynamic scale-models have been developed and evaluated in the wind tunnel. Significant improvement over the baseline vehicle has been observed which will be incorporated in final design
2. Initial load biasing evaluation completed
3. Concept material has been procured for mule vehicle test
4. Current engine tested at a BTE of 48.3% with additional technologies still to deploy
5. Technology concepts & targets established to move forward to Phase 3 (Design)



Development Area	Freight Efficiency Target
Weight	80+
Rolling/Parasitic	
Aerodynamics	
Engine	

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FE = Freight Efficiency (ton-miles/gal)